Shipboard Data Assimilation System/Doppler Radar

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LONG-TERM GOALS

Our goal is to develop a high-resolution shipboard data assimilation capability that can provide the Navy with improved analyses and forecasts of the atmospheric conditions with sufficient detail and accuracy for supporting the Navy mission in threat detection, weapons, and weather safe operations. The data assimilation software will utilize all available weather information, such as Doppler radar, in situ, and remotely sensed observations. The software will run efficiently and generate a detailed analysis of the atmosphere with sufficient accuracy to predict Electro-Magnetic/Electro-Optical (EM/EO) propagation and target area weather conditions. This information can then be fed back to SPY-1 radar and other weapon system operators to improve detection capabilities.

OBJECTIVES

Build a comprehensive data assimilation software suite for the on-scene (OS) version of the Coupled Ocean/Atmospheric Mesoscale Prediction System (COAMPS™). This data assimilation software will be able to analyze mesoscale weather by applying sophisticated analysis procedures capable of ingesting the information from Doppler radar, satellite, and other remote sensors. The primary focus of this effort will be to design a software system that optimally utilizes the available weather information such as SPY-1 Doppler radar for the NOWCAST system and for initializing COAMPS-OS™.

APPROACH

A mesoscale variational data assimilation system (3.5DVAR) is being jointly developed by the Naval Research Laboratory (NRL) and the University of Oklahoma (OU). This 3.5DVAR system uses the background fields provided by atmospheric predictions from COAMPS at non-synoptic times and/or by analyses from the newly developed NRL Atmospheric Variational Data Assimilation System (NAVDAS) at synoptic times. Simplified adjoint methods are used to achieve the high computational efficiency needed to assimilate high-resolution data from Doppler radars (including SPY-1 Tactical Environmental Processor) in space and time. The analysis increment fields are expressed by B-spline basis functions to optimally filter noise while the analysis is performed directly on the COAMPS grid. The assimilation time window is synchronized with COAMPS integration time steps and radar volumetric scans to enhance the coupling of the model with the data.

To compliment the radar assimilation system, a separate cloud analysis package was adapted for COAMPS from the OU Advanced Regional Prediction System (ARPS). The ARPS Data Analysis System (ADAS) is used to analyze high-resolution geostationary satellite observations (such as the GOES infrared and visible imagery), surface cloud observations, and reflectivity from radars. The

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14. ABSTRACT
Our goal is to develop a high-resolution shipboard data assimilation capability that can provide the Navy with improved analyses and forecasts of the atmospheric conditions with sufficient detail and accuracy for supporting the Navy mission in threat detection, weapons, and weather safe operations. The data assimilation software will utilize all available weather information, such as Doppler radar, in situ, and remotely sensed observations. The software will run efficiently and generate a detailed analysis of the atmosphere with sufficient accuracy to predict Electro-Magnetic/Electro-Optical (EM/EO) propagation and target area weather conditions. This information can then be fed back to SPY-1 radar and other weapon system operators to improve detection capabilities.

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ADAS cloud analysis provides estimates of cloud water and ice over a much larger region than is possible from using the 3.5DVAR system with the radar data alone. To ensure the accuracy of the cloud analysis, a cloud verification system has been developed to automatically verify the 3-D cloud products against satellite and surface observations.

WORK COMPLETED

Progress has been made in the fiscal year 2002 with adapting the 3.5DVAR wind and temperature retrieval system (Xu et al. 2001, Gu et al. 2001) to COAMPS. First, the system was extended to handle data from multiple (up to 17) radars at the same time. Second, a change in the estimation of background error covariance (Xu et al, 2001; Xu and Wei, 2001; Xu and Wei, 2002) further improves the accuracies of the retrieved fields from radar data. Third, data quality control was improved to ensure the radar data quality before being used by the 3.5DVAR system. Finally, the 3.5DVAR code has been upgraded to use COAMPS_3.0 (MPI) version data as background fields and real-time radar data as input. In addition, efforts have been made to acquire and process real-time radar data for in-house test and implementation of the 3.5DVAR system at NRL Monterey. Currently, real-time level-II data from nearly 50 NEXRAD stations over CONUS is being transmitted to NRL Monterey via the CRAFT project and processed every 6 minutes. Radar data from the archived SPY-1/TEP data and Navy's Supplemental Weather Radar (SWR) is also being processed. The radar capability in NRL Monterey now lays a solid foundation for in-house test and implementation of the 3.5DVAR and other radar data application systems.

Several improvements were also made to the ADAS cloud analysis in the last year. One of the improvements was the development of an interface that uses all geostationary satellite data around world. This allows ADAS to run in any regions where 3-D cloud analysis is needed. Another was the upgrade of the source code to use COAMPS_3.0 (MPI version) data as background fields. This was a big step toward integrating ADAS into the current COAMPS-OS systems for both nowcasting and data assimilation purposes. Because of the need to run ADAS on different computer platforms, the ADAS source code was also modified to eliminate the dependence on computer systems. Right now, ADAS can run on both UNIX and LINUX machines.

The ADAS cloud analysis system has gone through several extensive tests on a real-time basis at NRL Monterey with COAMPS-OS in many areas, including the East Coast and the West Coast of the US and a region in Afghanistan, producing hourly cloud analyses in some demonstration projects for the US Navy. Case studies were also performed to investigate the detailed structure of the analyzed clouds. During these tests, statistical scores were calculated using the automatic verification system to study the general performance of the system. In case studies, some specially designed validation algorithms were also used to investigate the impact of individual data on cloud analyses.

RESULTS

The 3.5DVAR radar assimilation system has been tested at NRL Monterey with both historical and real-time radar data. An interesting case was studied on September 19, 1999 when strong convective storms were approaching the east coast of Florida. The COAMPS model missed the storms as indicated by the very weak and smooth horizontal winds from the model forecast with smoothed convergence/divergence and vorticity fields and very weak upward winds along the east coast of Florida. By assimilating radar radial velocities observed by the NEXRAD located in Jacksonville, Florida using the 3.5DVAR, however, both the horizontal wind speed and direction were changed quite significantly in areas where storms were observed by the radar. A significant increase in upward

motion in the storm areas was also apparent (figures not shown). Another more recent case from July 24, 2002 when a strong storm moved to the east coast of North Carolina was also studied. Radar observations from the NEXRAD at Morehead City, North Carolina were obtained from the real-time CRAFT level-II data stream that is available at NRL Monterey. Figure 1 shows the 3.5DVAR horizontal wind analysis at 0.75km above the ground. It is very interesting to see the strong mesoscale vorticity and low-level convergence associated with the storm.

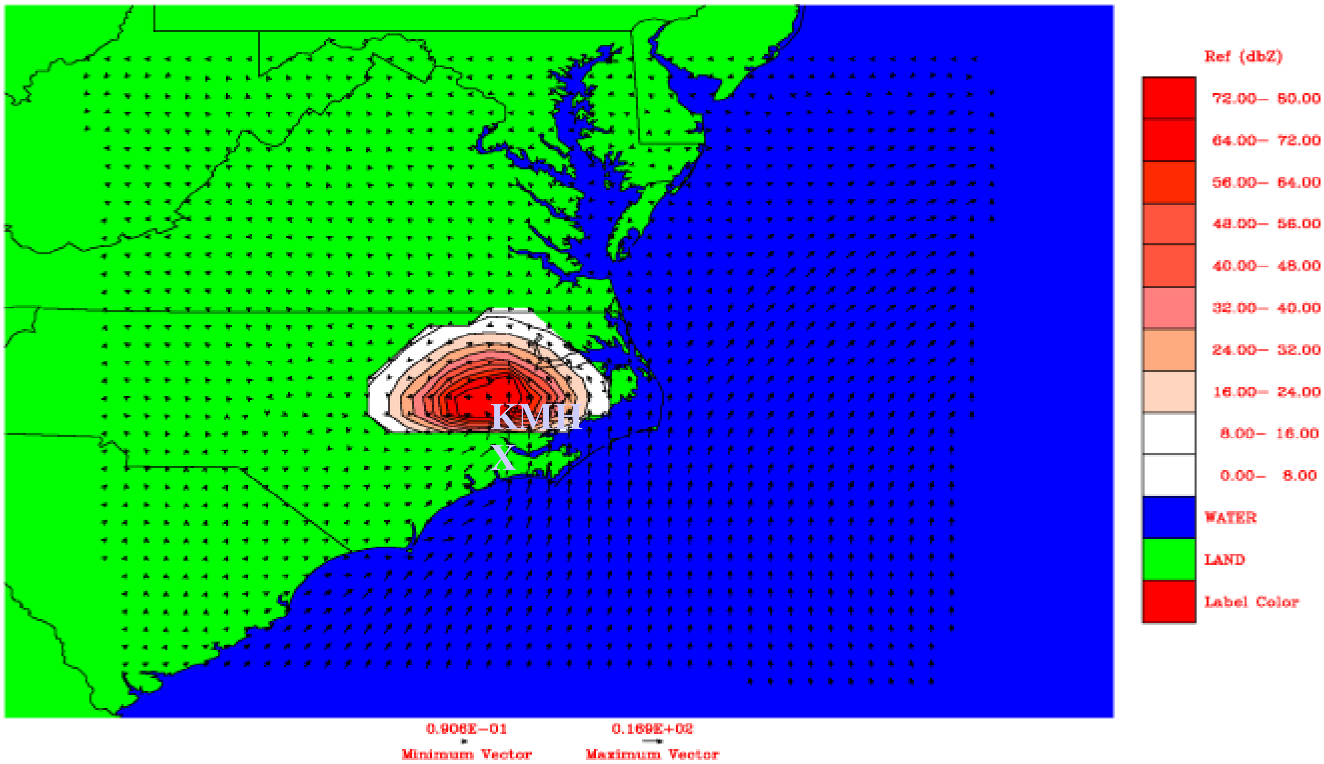

Figure 1 Horizontal wind (m/s) analyses at 20:00 UTC on July 24, 2002 from the 3.5DVAR. The winds are on a horizontal surface 0.75km above the ground. Contours (dbZ) are radar reflectivities observed by the KMHX radar in North Carolina.

Figure 2 presents the daily-mean monthly cloud top temperature correlations and standard deviations calculated from the ADAS cloud analyses and the COAMPS forecasts (for comparison) for the Afghanistan area in the2001-2002 winter season. The verification was done with MetoSat-5 brightness temperature. The COAMPS radiative transfer forward model was used in the calculation of the cloud top temperatures for both ADAS and COAMPS. The improvement in ADAS cloud top temperature is apparent, indicating the successful assimilation of the cloud information from satellite observations through the ADAS cloud analysis procedures. This kind of improvement can be seen in almost all the cloud analyses from ADAS. It should be mentioned, however, that the observational data used in the verification were also used in the cloud analysis. This means that the bias, a significant measure of system performance, could not be reflected in the statistics. To overcome this problem, an independent data source has been found for the cloud verification. It is radar composite reflectivity, a product from the NEXRAD level-III data. An example of such verification is given in Fig. 3 for a frontal system over the eastern US. The composite radar reflectivity in Fig. 3a was calculated from ADAS cloud liquid water, cloud ice, rain and snow mixing ratios using a simple radar reflectivity forward model

developed for the ADAS. Figure 3b gives the radar observed composite reflectivity from all radars in that area. It can be seen from Fig. 3 that ADAS basically re-produced the main structures and locations of the whole storm system, but with some fine storm structures missing because of the coarse grid resolution (21 km in this case).

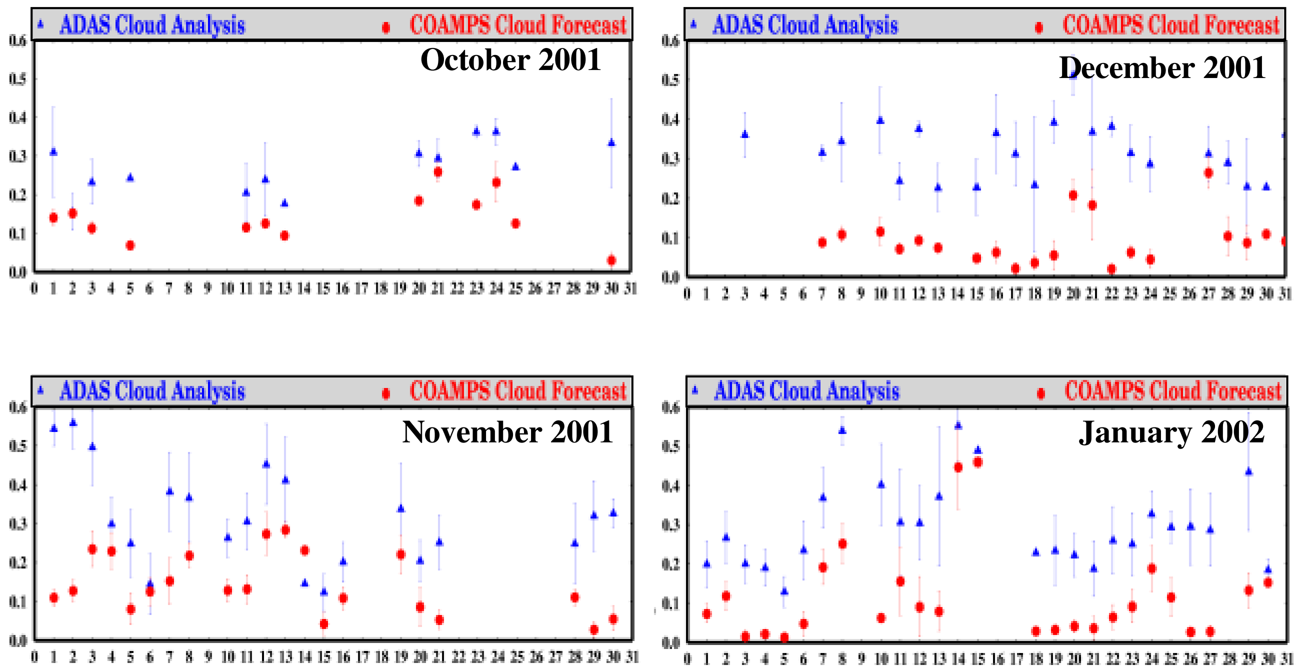

Figure 2 Daily-mean monthly statistic scores of the cloud top temperature correlation and standard deviation of ADAS cloud analyses and COAMPS forecasts verified against MeteoSat-5 observations over Afghanistan area.

IMPACT

The ADAS cloud analysis and the 3.5DVAR wind analysis systems that use geostationary satellite data, surface observations and radar measurements running in real-time with the COAMPS-OS will provide the Navy with near real-time, three-dimensional cloud and wind analyses in any region of interest to support the Navy's mission. The analysis fields can also be used for COAMPS model initialization to improve COAMPS initial conditions and hence the forecast, especially over the first few hours of the model integration. More importantly, some results from this research will be very useful in addressing some basic scientific questions regarding radar and satellite data retrieval, data quality control, mesoscale and small-scale data assimilation, and the impact of these retrieved data on regional, high-resolution model forecast.

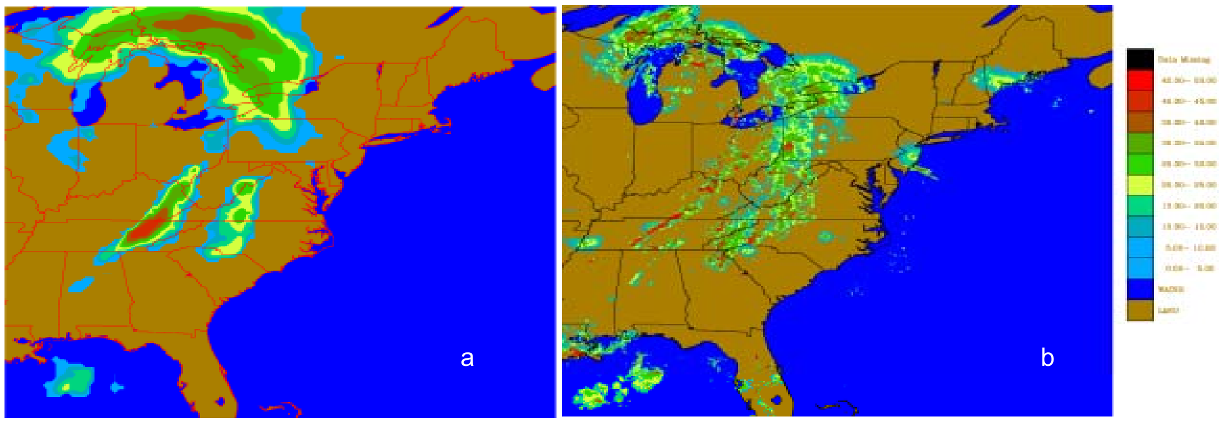

Figure 3 Radar composite reflectivites (dbZ) calculated from ADAS cloud and precipitation fields (a) and observed by the NEXRAD nexwork (b) at 00 UTC on September 20, 2001.

TRANSITIONS

The ADAS cloud analysis and the GOES IR forward model computer codes, adapted under this project, have been successfully integrated into COAMPS-OS in 6.4 programs (PE 0603207N, SPAWAR PMW-185).

RELATED PROJECTS

Related NRL base projects include BE-35-02-19, Data Assimilation and Analysis; BE 033-03-42, Multidimensional Data Assimilation Methodologies, and BE 35-2-56, Nowcasting the Atmospheric Battlespace Environment. Other related projects at NRL are funded by ONR (Nowcast for the Next Generation Navy) and SPAWAR PMW-155, task X2342 under PE 0603207N (Variational Assimilation and Physical Initialization; On-Scene Tactical Atmospheric Forecast Capability).

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